

Chapter 13 Reservoir Sedimentation

13-1. Introduction

"The ultimate destiny of all reservoirs is to be filled with sediment," (Linsley et al. 1992). The question is how long will it take? Also, as the sediment accumulates with time, will it adversely affect water control goals?

a. Transport capacity. A reservoir changes the hydraulics of flow by forcing the energy gradient to approach zero. This results in a loss of transport capacity with the resulting deposition. The smaller the particles, the farther they will move into the reservoir before depositing. Some may even pass the dam. Deep reservoirs are not fully mixed and are conducive to the formation of density currents.

b. Sediment deposits. The obvious consequence of sediment deposits is a depletion in reservoir storage capacity. Figure 13-1 illustrates components of sediment deposition in a deep reservoir. The volume of sediment material in the delta and the main reservoir depends on the inflowing water and sediment, reservoir geometry, project operation and life among other things. The delta will continue to develop, with time, and the reservoir will eventually fill with sediment.

13-2. Reservoir Deposition

a. Total available sediment. The first step is to estimate the total sediment that will be available for deposition during the design life of the project. Required data include design life of the reservoir, reservoir capacity, water and sediment yield from the watershed, the composition of the sediment material, and the unit weight of sediment deposits. With this information, the trap efficiency can be determined.

b. Trap efficiency. Trap efficiency is the percent of inflowing sediment that remains in the reservoir. Some proportion of the inflowing sediment leaves the reservoir through the outlet works. The proportion remaining in the reservoir is typically estimated based on the trap efficiency. Trap efficiency is described in Section 3-7(a) of EM 1110-2-4000, and the calculations are described in an appendix therein. The efficiency is primarily dependent on the detention time, with the deposition increasing as the time in storage increases.

c. Existing reservoirs. Existing reservoirs are routinely surveyed to determine sediment deposition, and resulting loss of storage. Section 5-30 and Appendix K of EM 1110-2-4000 describe the Corps program. This historic deposition data can be useful for checking computed estimates. "Sediment Deposition in U.S. Reservoirs (Summary of Data Reported 1981-85)" provides

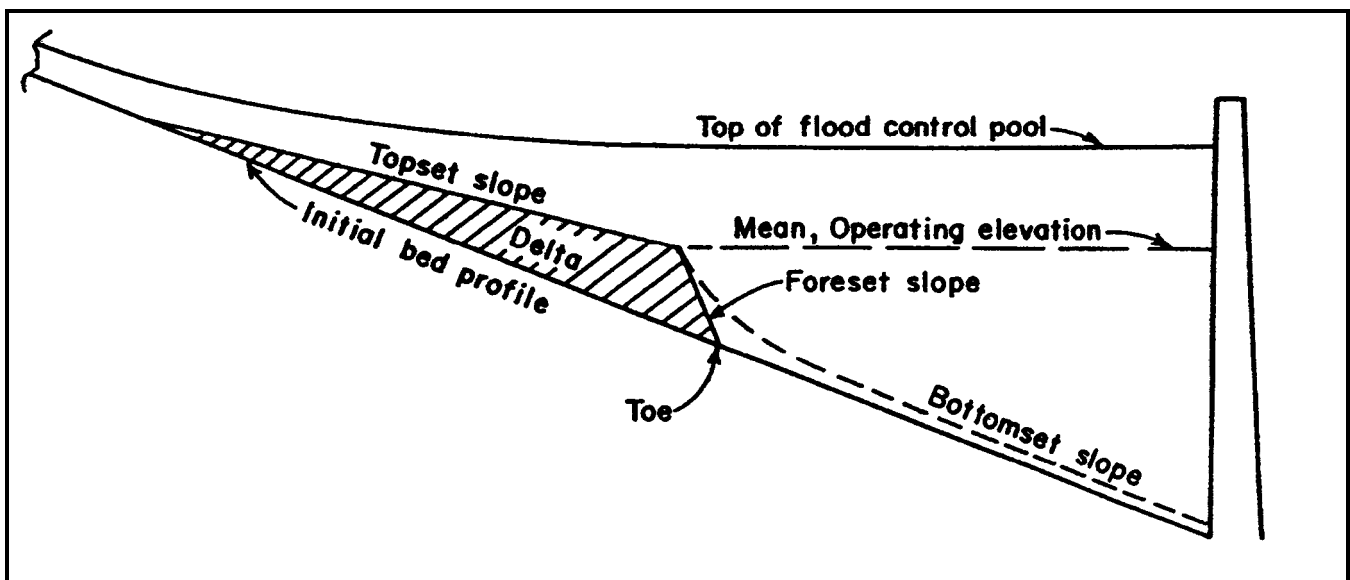


Figure 13-1. Conceptual deposition in deep reservoirs

data on reservoir locations, drainage areas, survey dates, reservoir storage capacities, ratios of reservoir capacities to average annual inflows, specific weights (dry) of sediment deposits, and average annual sediment-accumulation rates (U.S. Geological Survey 1992). Reservoirs are grouped by drainage basins.

13-3. Distribution of Sediment Deposits in the Reservoir

The planning or design of a reservoir requires an analysis to determine how sediment deposits will be distributed in the reservoir. This is a difficult aspect of reservoir sedimentation because of the complex interaction between hydraulics of flow, reservoir operating policy, inflowing sediment load, and changes in the reservoir bed elevation. The traditional approach to analyzing the distribution of deposits has relied on empirical methods, all of which require a great deal of simplification from the actual physical problem.

a. Main channel deposition. Conceptually, deposition starts in the main channel. As flow enters a reservoir, the main channel fills at the upstream end until the elevation is at or above the former overbank elevations on either side. Flow then shifts laterally to one side or the other, but present theory does not predict the exact location. During periods of high water elevation, deposition will move upstream. As the reservoir is drawn down, a channel is cut into the delta deposits and subsequent deposition moves material farther into the reservoir. The lateral location of the channel may shift from year to year, but the hydraulic characteristics will be similar to those of the natural channel existing prior to impounding the reservoir. Vegetation will cover the exposed delta deposits and thus attract additional deposition until the delta takes on characteristics of a floodplain.

b. Sediment diameters. The diameter of sediment particles commonly transported by streams ranges over five log cycles. Generally, the coarse material will settle first in the outer reaches of the reservoir followed by progressively finer fractions farther down toward the reservoir dam. Based on this depositional pattern, the reservoir is divided into three distinct regions: top-set, fore-set, and bottom-set beds. The top-set bed is located in the upper part of the reservoir and is largely composed of coarse material or bed load. While it may have a small effect on the reservoir storage capacity, it could increase upstream stages. The fore-set region represents the live storage capacity of the reservoir and comprises the wash load. The bottom-set region is located immediately upstream of the dam and is

primarily composed of suspended sediments brought from upstream by density currents. The region is called the reservoir dead storage and generally does not affect the storage capacity. Some of the finest material may not settle out and will pass through the dam. In order to calculate the volume of material which will deposit as a function of distance, grain size must be included as well as the magnitude of the water discharge and the operating policy of the reservoir.

c. Reservoir shape. Reservoir shape is an important factor in calculating the deposition profile. For example, flow entering a wide reservoir spreads out, thus reducing transport capacity, but the path of expanding flow does not necessarily follow the reservoir boundaries. It becomes a 2-dimensional problem to calculate the flow distribution across the reservoir in order to approximate transport capacity and, therefore, the resulting deposition pattern. On the other hand, flow entering a narrow reservoir has a more uniform distribution across the section resulting in hydraulic conditions that are better approximated by 1-dimensional hydraulic theory.

d. Flood waves. Flood waves attenuate upon entering a reservoir. Therefore, their sediment transport capacity decreases from two considerations: (1) a decrease in velocity due to the increase in flow area and (2) a decrease in velocity due to a decrease in water discharge resulting from reservoir storage. As reservoir storage is depleted by the sediment deposits in the delta, the impact of attenuation on transport capacity diminishes. The resulting configuration, therefore, is assumed to depend upon the first consideration, whereas, the time for delta development is influenced somewhat by the second consideration.

e. Flood-pool index method. If flood control is a project purpose, the next level of detail in reservoir sedimentation studies is to divide the total volume of predicted deposits into that volume settling into the flood-control pool and that volume settling in the remainder of the reservoir. The flood-pool index method requires the depth of flood-control pool, depth of reservoir, and the percent of time the reservoir water level is at or above the bottom of the flood-control pool. Based on the index, the percent of sediment trapped in the flood-control pool is estimated by a general empirical relationship. Appendix H of EM 1110-2-4000 describes the index method and provides several other methods for estimating the distribution of sediment deposits in reservoirs. Chapter 5, Section IV, EM 1110-2-4000, provides an overview of levels of sedimentation studies and methods of analysis.